

The Odonata of Fort A. P. Hill and Vicinity, Caroline County, Virginia

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The Odonata fauna of Virginia is fairly diverse with more than 180 species currently known. The most recent summaries of this fauna are those of Carle (1979, 1982, 1991) for Anisoptera (dragonflies) and Roble (1994b) for Zygoptera (damselflies). The extensive listing of all known dragonfly records from Virginia that is provided by Carle (1982) reveals that numerous counties in the state (e.g., Amelia, Amherst, Caroline, King and Queen, King George) have been virtually unsampled for Odonata.

In the fall of 1991, the Virginia Department of Conservation and Recreation's Division of Natural Heritage (DCR-DNH) was contracted by the U.S. Department of Defense (Department of the Army) to conduct a survey for rare animals, plants, and significant natural communities on the Fort A. P. Hill Military Reservation in Caroline County, Virginia. Subsequently, DCR-DNH was contracted in 1994 by the state's Chesapeake Bay Local Assistance Department to conduct a similar survey of the Polecat Creek watershed in Caroline County as part of a grant funded by the National Oceanic and Atmospheric Administration (NOAA) to study the effects of increased development on the watershed during the next decade.

Although no attempt was made to conduct a comprehensive survey of the fauna or flora of Fort A. P. Hill, initial surveys of the base by DCR-DNH (hereafter shortened to DNH) biologists revealed the presence of numerous naturally acidic wetlands, and a large and widespread population of the carpenter frog (*Rana virgatipes* Cope), a rare to uncommon species (Pague, 1991) in Virginia. These and subsequent surveys also documented the presence of numerous rare plants (Fleming & Van Alstine, 1994), as well as other uncommon amphibians and reptiles, including the lesser siren (*Siren intermedia* LeConte), greater siren (*S. lacertina* Linnaeus) and rainbow snake (*Farancia erythrogramma* [Beauvois]), at or near the northern limits of their

geographic ranges (Roble & Hobson, 1994; Roble, 1995).

The fortuitous discovery on 17 June 1993 of *Nannothemis bella* (Uhler), a dragonfly that had not been seen in Virginia in more than a century (Roble & Stevenson, 1994), prompted us to sample the Odonata of the base more intensively. The senior author maintained records of all species that were observed or collected on subsequent surveys that he conducted alone or with the junior author. The latter maintained partial species lists for the few surveys that he conducted alone. Our collective records form the primary data source for this paper. We have supplemented the Fort A. P. Hill records with data collected during the Polecat Creek surveys, as well as very limited surveys of three ponds located elsewhere in Caroline County.

Carle's (1982) exhaustive survey of Virginia dragonfly specimens confirmed the presence of only two species (*Aeshna umbrosa* Walker and *Gomphus exilis* Selys) from Caroline County, whereas several of the damselfly species discussed below were previously reported from this county by Roble (1994b), largely on the basis of records obtained at Fort A. P. Hill.

STUDY AREAS AND METHODS

Caroline County encompasses 342,695 acres in eastern Virginia approximately midway between Richmond and Washington, D.C. The Fall Zone separating the Coastal Plain and Piedmont physiographic provinces lies in the western portion of the county. All but three of our sampling sites fall within the Coastal Plain. Two sites are in the Fall Zone and a third spans the Piedmont-Fall Zone transition area.

Fort A. P. Hill Military Reservation occupies the northeastern portion of Caroline County and covers 75,944 acres, or about 22% of the county (Fleming & Van Alstine, 1994). Less than 100 acres at the east end of

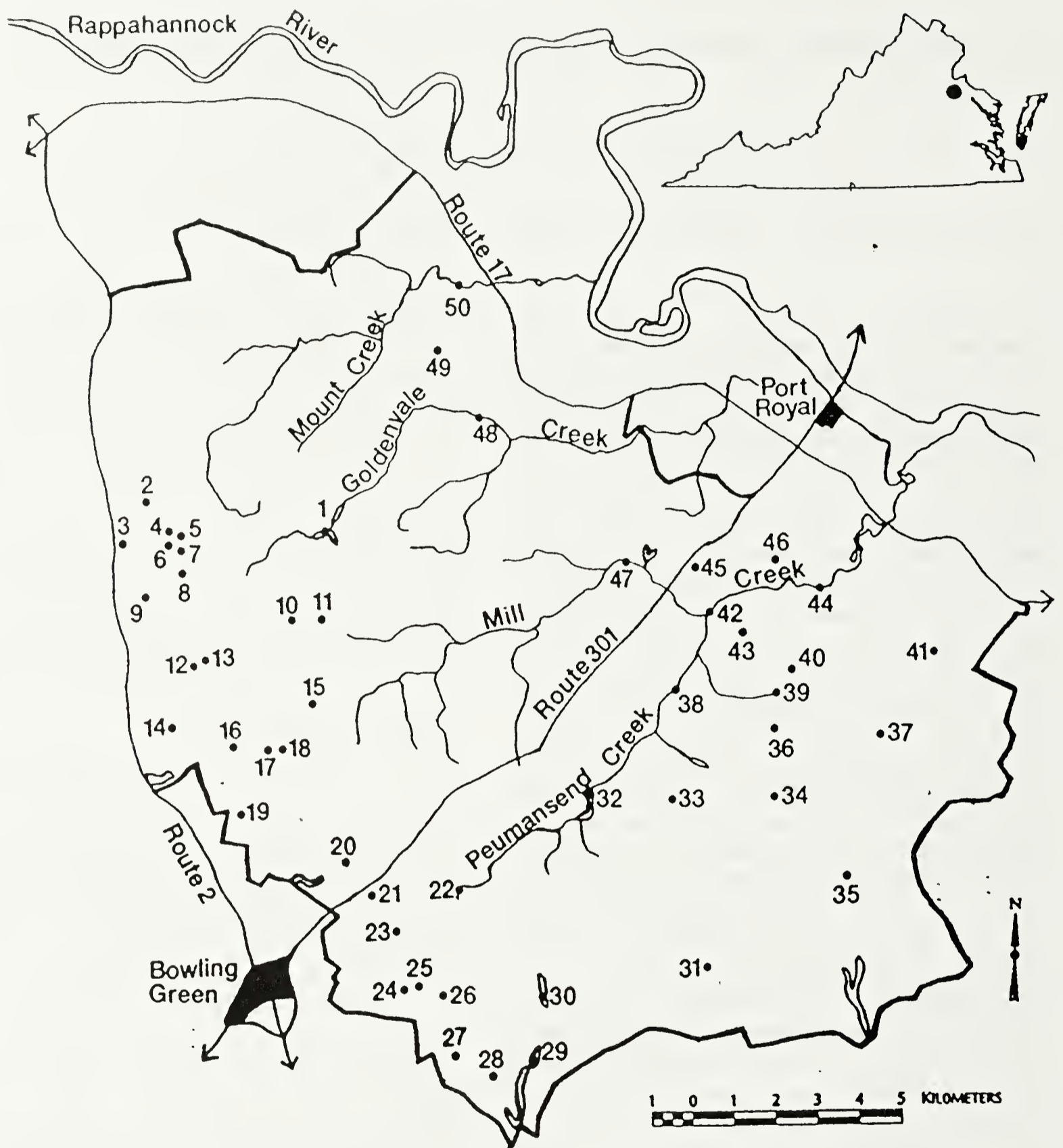


Figure 1. Location of Odonata sampling sites on Fort A. P. Hill, Caroline County, Virginia.

the base lie in adjacent Essex County, but none of our surveys were conducted in these areas. Route 301 bisects the base into north and south portions. Prior to the establishment of the base in 1942, the land was primarily used for agricultural and forestry purposes. Currently, more than 80% of the base is forested. Elevations on Fort A. P. Hill range from 20 to 250 feet (6 - 76 m), with a number of moderately deep ravines occurring in the northeastern portion of the base.

The majority of the wetlands that were surveyed for Odonata on Fort A. P. Hill consisted of acidic beaver ponds. We made virtually no effort to survey any of the man-made ponds or reservoirs on the base. We also sampled numerous forested and some open seepage habitats, as well as several small streams. Most of the streams on the base have been impounded by beavers at numerous locations or are of low gradient, and thus do not support many lotic species. Mill Creek and its primary tributary (Peumansend Creek) are the major lotic habitats on the base. These are sand-bottomed streams ranging from 2-5 m in width. The Rappahannock River occurs within a few kilometers of the base to the east and forms the northeastern boundary of Caroline County. The Mattaponi River lies several kilometers west of the base boundary.

The locations of sampling sites where Odonata were documented on Fort A. P. Hill are identified in Figure 1. Site numbers 1-50 that appear in the annotated species accounts later in this paper refer to the locations plotted on this map. The habitats associated with the various collecting sites are as follows: ponds (sites 2-13, 15-20, 22-25, 27-31, and 36-37), streams (sites 14, 16, 38, 42, 44, 47-48, and 50), seepage areas (sites 15, 22, 26, 33-35, 39, 41, 43, 45-46, and 49), man-made lakes (1 and 32), swamps (44), and roads (21, 34, 40-41, and 43-44). Seven of the sites were placed in two or more of the above categories. Our access to the sites varied considerably depending on military training schedules and safety concerns related to the potential presence of unexploded ordnance in some areas on the southern portion of the base. While several sites were visited on multiple occasions, many were surveyed only once. Unfortunately, several of the finest wetlands on the base could not be thoroughly sampled for Odonata because they were in areas with very limited access.

Virtually all of our records of Odonata from Fort A. P. Hill are based on observations or collections of adults.

Many of these records were obtained incidental to our larger objective of surveying the base for rare animals. Sampling for Odonata larvae was limited to surveys of forest seepage habitats, including the headwaters of small streams. Voucher specimens were obtained for most species. Species documented only by sight records are identified as such in the annotated accounts. Specimens are deposited primarily in the collection of the National Museum of Natural History (Smithsonian Institution, Washington, D.C.); additional specimens have been or will be deposited in the Virginia Museum of Natural History (Martinsville) and the Florida State Collection of Arthropods (Gainesville).

Odonata surveys by DNH zoologists at Fort A. P. Hill spanned the period from 10 September 1992 to 17 July 1995. A dozen adult specimens collected by Philip H. Stevenson on the former date constitute the extent of Odonata sampling during that year. He also collected about 15 adult and larval specimens in the spring and early summer months of 1993. We initiated a more intensive survey of the Odonata fauna of the base beginning in July 1993 and extending through November of that year. The senior author continued this survey on a more limited basis in 1994 and 1995, adding 20 species to the confirmed list in the process.

Polecat Creek is a tributary of the Mattaponi River and is located approximately 15-20 km southwest of Fort A. P. Hill. Stevens Mill Run is a primary tributary of Polecat Creek. Both of these streams originate in the Piedmont and terminate in the Coastal Plain. Aquatic habitats vary considerably within the Polecat Creek drainage and provide for a diversity of Odonata species. In the Fall Zone region of the watershed and areas further west, benthic substrates in Polecat Creek and its tributaries are of mixed composition. Areas of cobble and boulder substrates are interspersed with gravel beds, clay banks, and pockets of sand. East of the Fall Zone, substrates become more uniform, consisting of sand bars and mucky sand, with only scattered rocks. The floodplain east of the Fall Zone is typically much broader, providing habitat for species typically found in low gradient streams and floodplain pools. While beaver impoundments are common within the watershed, there are extended stretches of lotic habitats with numerous riffles, runs and deeper pooled sections. Funderburg (1974) described the swamp habitat present near the U.S. Route 301 crossing of Polecat Creek, approximately 1 km upstream from its

mouth.

Surveys for Odonata in the Polecat Creek watershed were conducted between 18 May and 4 October 1994 by the junior author in conjunction with more comprehensive surveys for rare animals. In addition to sampling Polecat Creek near several bridge crossing sites, adult Odonata that were encountered during continuous stream surveys for mussels were noted. Several lentic habitats in the watershed were also sampled. The senior author collected two gomphid larvae in Stevens Mill Run on 16 March 1995, which constitute our only Odonata records for this stream. The following sites and their corresponding numbers appear in the annotated species accounts:

51. Stevens Mill Run at County Route 601, ca. 1 km NE of Golansville (Piedmont/Fall Zone)
52. Polecat Creek upstream (west) of U.S. Route 1 (Fall Zone)
53. Polecat Creek at County Route 652, ca. 2 km SE of Golansville (Fall Zone)
54. Polecat Creek at County Route 601, 0.3 km SE of Penola
55. Polecat Creek at powerline crossing, just downstream of U.S. Route 301
56. Sphagnous seepage area in powerline right-of-way ca. 0.8 km SE of Coleman's Millpond (= Mill Run at County Route 656).
57. Beaver ponds and sphagnous seepage area along Polecat Creek at powerline right-of-way upstream from County Route 601 crossing.

Three additional ponds in Caroline County were surveyed only very briefly by the senior author, but each was inhabited by at least one uncommon or state-rare species of Odonata, and they are thus worthy of inclusion in this report. Further sampling of these sites is desirable.

58. Beaver pond near headwaters of Downers Branch, ca. 1.5 km NW of Paige
59. Pond along County Route 654, ca. 1.3 km SW of Peatross
60. Pond along County Route 656, ca. 2.5 km SE of Peatross

Adult specimens collected during our surveys were identified using the following references: Carle (1982),

Carpenter (1991), Dunkle (1989, 1990), Johnson & Westfall (1970), Needham & Heywood (1929), Needham & Westfall (1955), Walker (1953, 1958), and Walker & Corbet (1975). The few larvae that we collected were identified using the keys of Huggins & Brigham (1982) and Needham & Westfall (1955). We also examined the damselfly collection of the National Museum of Natural History (USNM) for any records from Caroline County.

RESULTS

We documented 77 species of Odonata (25 damselflies and 52 dragonflies) on Fort A. P. Hill. Seven of these species were not vouchered and one of our sight identifications is tentative. Both of the species reported from Caroline County by Carle (1982) are present on the base. Of the 76 confirmed species, 12 (15.8%) are monitored by the Division of Natural Heritage as state-rare species (Roble, 1996). This is proportionately much less than the fraction of the state's Odonata fauna (46.2%; 39.9% excluding the Gomphidae) that is currently monitored by DNH. We also documented another 20 species on Fort A. P. Hill that are uncommon or locally distributed in Virginia, and are included on the Natural Heritage "Watch List" (Roble, in prep.). The documented Odonata fauna of Fort A. P. Hill represents 42.3% of the state's fauna (excluding accidentals). The large families Coenagrionidae and Libellulidae are fairly well represented on the base, whereas the Gomphidae are not (Table 1). The geographic location of the base (i.e., Coastal Plain) and its lack of suitable lotic habitats are largely responsible for the depauperate gomphid fauna. A total of 24 species was recorded in the Polecat Creek watershed, including four (one state-rare and one watch list species) that were not found at Fort A. P. Hill. Two other species are represented in the USNM collection, resulting in a total of 82 species confirmed for the county.

The extreme dates on which adult Odonata were observed during our surveys were 18 April and 22 November. The seasonal distribution of all species is presented in Table 2, which follows the format of Shiffer & White (1995). No data are available for 13 of the 32 quarters included in this table (these quarters are underlined). Flight date records that equal or exceed those listed in Carle (1982) and Roble (1994b) for Virginia dragonflies and damselflies, respectively, are denoted by an asterisk in the last column of the table.

Table 1. Species diversity of Odonata on Fort A.P. Hill as compared to the Odonata fauna of Virginia.

FAMILY	FORT A.P. HILL	VIRGINIA	PERCENT
Calopterygidae	2	7	28.6
Lestidae	5	10	50.0
Coenagrionidae	18	37	48.6
Total Zygoptera	25	54	46.3
Petaluridae	1	1	100.0
Aeshnidae	8	16	50.0
Gomphidae	6	39 ^a	15.4
Cordulegastridae	4	5	80.0
Corduliidae	8	24	33.3
Macromiinae	2	5	40.0
Corduliinae	6	19	31.6
Libellulidae	25	43 ^b	58.1
Total Anisoptera	52	128	40.6
Total Odonata	77	182	42.3

^aExcludes one reported but unconfirmed species

^bExcludes two accidental species

Some of the early and late dates reported by Roble (1994b) are based on our observations in Caroline County. It should be noted that Carle's (1982) survey of available specimens to determine Virginia flight dates for dragonflies was far more exhaustive than Roble's (1994b) survey of damselflies. Consequently, asterisked early or late dates for damselflies in Table 2 should only be regarded as the extreme published dates for Virginia.

An annotated list of the Odonata species recorded from Caroline County follows. The format is similar to that used by Cross (1955), except that we do not report the total number of specimens obtained for most species. Scientific names and authors follow Garrison (1991) with the exceptions discussed by Donnelly & Tennessen (1994), Roble (1994b), and Tennessen (1994). As noted previously, site numbers 1-50 are on Fort A. P. Hill and refer to locations plotted in Figure 1. The locations of sites 51-60 were defined above. Collection or observation records that extend the Virginia flight season of a species

beyond the dates reported by Carle (1982) and Roble (1994b) are indicated by an asterisk or discussed in the text. We have included previously unpublished distributional records (particularly county records) for selected uncommon or state-rare species based on DNH surveys during the past six years.

ANNOTATED LIST OF ODONATA RECORDED FROM CAROLINE COUNTY

Zygoptera

CALOPTERYGIDAE

Calopteryx dimidiata Burmeister

Sites 38, 42, and 54. 18 May - 28 July. This species was moderately common along a 100 m section of Mill Creek at site 42, where 15-20 adults were observed by SMR on 8 July 1994. A single male was seen by CSH along Polecat Creek at site 54 on 18 May 1994. This record was the basis for the early flight date listed in Roble (1994b). DNH zoologist Dirk J. Stevenson subsequently captured *C. dimidiata* on 7 May 1995 in Greenville County. In addition to our records, the USNM has specimens collected on 18 June 1980 at County Route 630 (= Beverly Run crossing), 1 mi (= 1.6 km) W of Central Point in the extreme southeastern corner of Caroline County.

Calopteryx maculata (Beauvois)

Sites 3, 7, 15, 29-30, 38, 41-44, 50, 52, and 54. 18 May - 16 August. Common along small streams on Fort A. P. Hill, including sluggish seepage headwaters as well as faster flowing streams such as Mill Creek. Found at all sites where the previous species occurred, but in greater abundance (e.g., five times as many *C. maculata* as *C. dimidiata* were observed at site 42). This species was also common along Polecat Creek. Our earliest record precedes the early flight date listed for Virginia in Roble (1994b) by three days, but *C. maculata* was later found on 7 May 1995 in Greenville County with *C. dimidiata* (D. J. Stevenson, pers. comm.).

LESTIDAE

Lestes congener Hagen

Documented only by an adult male that was collected by CSH at site 22 on 4 October 1993.

Lestes disjunctus australis Walker

Sites 10, 11, 22, and 36. 25 April - 4 October. This species is apparently less widespread on Fort A. P. Hill than might be expected. Numerous teneral were observed by SMR at site 11 on 1 June 1994.

Lestes inaequalis Walsh

Sites 3, 4, 10, 23, 44, 54, and 59. 16 June - 1 September. Uncommon at a few acidic beaver ponds. Maximum count was four adults observed at site 10. Our late date exceeds that reported in Roble (1994b) by one week, but a female was subsequently captured by Dirk J. Stevenson on 13 September 1995 along the Blackwater River straddling the Isle of Wight-Southampton county line. This record and two males that Dirk collected in Greensville County are additions to the county records listed for *L. inaequalis* in Roble (1994b).

Lestes rectangularis Say

Our only records for Fort A. P. Hill are of an adult male that was collected by Philip H. Stevenson at site 17 on 10 September 1992, and an adult female collected by CSH at site 3 on 17 August 1993. This species was also found by CSH at several small ponds along Polecat Creek (sites 55 and 57) on 11 August 1994. Presumably, *L. rectangularis* is much more common in Caroline County than our few records suggest, because it is the most common and widespread member of the genus in Virginia (Roble, 1994b).

Lestes vigilax Hagen

Recorded at 19 sites on Fort A. P. Hill; also sites 54, 59, and 60. 24 June - 4 October. This species inhabits numerous acidic beaver ponds on the base, but is otherwise uncommon in Virginia (Roble, 1994b).

Highest counts were 150+ adults at site 30 and 50+ adults at sites 8, 29, 59, and 60. Dunkle (1990) reported that this species prefers acidic habitats.

COENAGRIONIDAE

Argia apicalis (Say)

Several individuals of this species were observed by CSH along Polecat Creek at site 54 on 17 June 1994, but no collections were made.

Argia bipunctulata (Hagen)

Sites 22, 26, 35, and 56. 8 July - 4 October. All of our sites are open seepage habitats, which is typical of this locally distributed species (Dunkle, 1990). About 20 adults were observed at sites 35 and 56. This species is apparently most abundant at site 26 (probably hundreds of adults), which was barely explored due to the high potential for unexploded ordnance. As noted by Roble (1994b), 4 October is a rather late flight date for this species (two males collected at site 22). Recent surveys by DNH botanist J. Christopher Ludwig have added Greensville and Lee counties to the records listed for *A. bipunctulata* in Roble (1994b).

Argia fumipennis violacea (Hagen)

Sites 4, 11, 17-18, 27, 29-30, 32, 37-38, and 52-54. 31 May - 4 October. Common along streams and near outlets of beaver ponds.

Argia moesta (Hagen)

The USNM collection includes a male captured on 12 June 1978 at the County Route 730 (= Route 738?) bridge crossing of the North Anna River at the southern boundary of the county. The label associated with this specimen apparently is in error because we cannot locate a Route 730 bridge crossing on a map of the county and suspect that the route number is actually 738. We did not find this species during our surveys.

Argia tibialis (Rambur)

Sites 30, 38, 42, 44, and 54. 18 May* - 28 July.

Found along streams and near outlets of beaver ponds (site 30). Adults seen by CSH along Polecat Creek (site 54) on 18 May extend the earliest date reported for this species in Virginia (Donnelly, 1961; Roble, 1994b) by 12 days.

Chromagrion conditum (Hagen)

Sites 20 and 31. 25 April - 29 April. This early species is probably more common than our records indicate. At least 17 mated pairs were observed by SMR at site 31 on 25 April 1994.

Enallagma aspersum (Hagen)

Documented only by an adult male that was collected by CSH at site 3 on 17 August 1993.

Enallagma civile (Hagen)

Found only at site 28 on 27 September 1993, where it was very common (50+ adults).

Enallagma daeckii (Calvert)

Sites 3, 18, 26, 30, 31, and 44. 31 May - 28 July. Numerous teneral and a few mature adults were found by SMR at sites 3 and 18 on 31 May 1994. Highest count was 250+ adults at site 30 on 8 July 1994.

Enallagma divagans Selys

A male was collected by CSH from emergent vegetation along Polecat Creek at site 54 on 17 June 1994.

Enallagma dubium Root

Sites 4, 8, 18, 28, and 37. 24 June - 27 September. This species is probably more common than our records indicate. It is inconspicuous and appears to be active primarily in mid to late afternoon. All of our observations were made at acidic beaver ponds (see also Roble, 1994b). Two mating pairs were among 11 adults observed by SMR at site 4 on 13 September 1993. Only 1-5 adults were seen at the other sites, including several that were captured during rainy or cool conditions on 27 September 1993.

Gloyd (1951) reported that *E. dubium* was common at a swampy pond near the Dismal Swamp in the City of Suffolk (formerly Nansemond County). This is the only other published record for this species in Virginia. Matta (1978) did not find *E. dubium* in southeastern Virginia.

Enallagma exsulans (Hagen)

The USNM has five specimens (including one pair) that were taken with the *Argia moesta* specimen discussed above. We did not observe this species during our surveys, although it may occur along portions of Mill Creek and Polecat Creek.

Enallagma geminatum Kellicott

Sites 2, 4, and 5. 18 August - 13 September. This species was found primarily on lily pads. At least ten adults were seen at sites 4 and 5, whereas only a single male was found at site 1.

Enallagma signatum (Hagen)

Sites 3-4, 7-8, 18, 30, and 37. 31 May - 27 September. This species is probably more common than our records indicate. The majority of our sightings were made in late afternoon when this species is most active. Fewer than ten individuals were observed at each site.

Enallagma traviatum Selys

Documented only by an adult male that was collected by SMR at site 18 on 24 June 1994. This specimen is assignable to the nominate subspecies (Roble, 1994b). Donnelly's (1973) range map does not show any records of this species from Virginia, but Roble (1994b) provided several records.

Enallagma vesperum Calvert

Sites 3, 8, and 18. 31 May - 12 August (teneral male collected on latter date). This crepuscular species is probably more common than our records indicate. Only a few individuals were observed by SMR at each site. Most were found on lily pads.

Ischnura hastata (Say)

Recorded at 16 sites on Fort A. P. Hill as well as sites 58 and 60. 25 April - 4 October. This species inhabits numerous ponds on the base, although adults are sometimes clustered in discrete areas around a particular pond.

Ischnura kellicotti Williamson

Sites 3, 8, 18, 20, and 59. 31 May - 12 August. This species was found on lily pads, often in the company of the similarly marked *Enallagma geminatum*. At least ten individuals were observed by SMR at all sites except site 3 during surveys of only a small fraction of the lily pads present at each site.

Ischnura posita (Hagen)

Recorded at 25 sites on Fort A. P. Hill as well as seven of the 10 off-base sites. 18 April - 4 October. This is the most common and widespread damselfly species on Fort A. P. Hill, and elsewhere in the county.

Ischnura ramburii (Selys)

Sites 18, 27-29, 36-37, and 54. 25 April - 27 September. Only a few individuals were observed at each site.

Nehalennia integricollis Calvert

Sites 3-4, 11, 26, and 30. 1 June - 13 September. Only single individuals were found at sites 3, 4, and 11 (two dates at latter). At least 200 adults were observed by SMR at site 30 on 8 July 1994, making it the largest population known in the state (Roble, 1994b). A large population may also inhabit site 26, but this area was barely explored because of safety concerns. The only other documented sites for *N. integricollis* in Virginia are from Augusta County and the City of Suffolk (Gloyd, 1951; Roble, 1994b).

Telebasis byersi Westfall

The population discovered by SMR on 17 July 1995 at site 44 is the northernmost known locality within the range of this species and one of only two documented

sites in Virginia (Roble & Stevenson, 1996). Eleven adults were seen during a very brief survey (<15 min), suggesting that a thriving population inhabits this area.

Anisoptera

PETALURIDAE

Tachopteryx thoreyi (Hagen)

Sites 15, 18, 30, and 49. 27 May - 28 July. All records of this large, primitive dragonfly were obtained by SMR. One female was collected and two others were photographed. Only one or two individuals were recorded at each site, including a tandem pair that was observed very briefly at 1845 h on 8 July 1994 (site 15). The pair quickly flew away and landed in the forest canopy, where they reportedly mate (Dunkle, 1981). One adult female at site 18 repeatedly chased patrolling males of *Libellula hydia* when they flew near her perch on the trunk of a tall snag beside the pond's edge. She made no effort to pursue several males of *L. deplanata* that landed nearby. One adult landed briefly on the shoulder of SMR at site 30. Dunkle (1981) reported similar "tame" behavior in a Florida population. No larvae or exuviae were found despite numerous surveys of forested seepage areas.

Carle (1982) recorded this species from 13 Virginia counties. In an earlier paper (Carle, 1979) on the rare dragonflies of Virginia, he indicated that only seven extant populations of this species were known in the state and classified *T. thoreyi* as a "locally distributed species." Recent surveys by DNH zoologists have resulted in the discovery of several previously unknown populations of this species at widely scattered sites in Virginia. We have also been informed of other newly discovered populations in the state (M. Stinson, pers. comm.).

AESHNIDAE

Aeshna umbrosa Walker

Two males were observed by SMR on 17 July 1995 while patrolling over a short section of Mill Creek at site 44. Carle (1982) previously reported this species from Caroline County; a female was collected at an unknown locality within the county on 20 October 1973.

Anax junius (Drury)

Recorded at 18 sites on Fort A. P. Hill; also site 59. 25 April - 27 September. This species is common and widespread on the base.

Anax longipes Hagen

Sites 28 and 30. 8 July - 28 July*. This large, unmistakable species is reported solely on the basis of sight records obtained by SMR. Three to five males were observed at site 30 on 28 July 1993; one male and one female were seen there on 8 July 1994. A single male was also observed at site 28 on the latter date. Carle (1982) reported *A. longipes* from three widely scattered counties (Augusta, Charles City, and Lee) in Virginia, his latest date being 17 July. In an earlier paper (Carle, 1979), he included this primarily austral species in his list of the state's rare dragonflies on the basis of only two known extant populations. DNH zoologist Dirk J. Stevenson (pers. comm.) observed two *A. longipes* on 30 May 1995 at a man-made sandpit pond on the Fort Story Military Reservation in the City of Virginia Beach.

Basiaeschna janata (Say)

Sites 4, 14, 16, and 47. 28 April - 29 April. This early species is probably more common than our records indicate. At least five adults were observed by SMR at sites 14 and 47.

Boyeria vinosa (Say)

Sites 27, 42, 53 (adults and larvae), and 54. 7 July - 4 October. This species is probably more common than our records indicate.

Epiaeschna heros (Fabricius)

Sites 14, 52, and 54. 29 April - 12 August. This species is reported solely on the basis of sight records. Only one or two individuals were seen at each site. Our early date equals that listed in Carle (1982) for Virginia, although the species has been seen as early as 9 April (1995) in Greensville County (D. J. Stevenson, pers. comm.).

Gomphaeschna furcillata (Say)

Sites 4, 14, 16, and possibly 20. All records of this species at Fort A. P. Hill were obtained on 29 April during the Spring 1995 field trip of the Virginia Herpetological Society. A male was netted at site 4 by Michael D. Killian and a female was captured by Dirk J. Stevenson along the road bordering site 16. Several adults were also observed by SMR at sites 14 and 16; one possible sighting was made at site 20. Carle (1982) recorded this species from eight counties and cities in Virginia. However, he listed only one known extant population in the state in his paper (Carle, 1979) on rare dragonflies. Recent surveys by DNH zoologists have confirmed approximately ten additional populations in eastern Virginia.

Nasiaeschna pentacantha (Rambur)

Documented only by an adult female that was collected by SMR at site 3 on 31 May 1994. Carle (1982) recorded this species from three counties and cities in southeastern Virginia, his earliest flight date being 1 June.

GOMPHIDAE

Arigomphus villosipes (Selys)

Sites 18 and 23. 31 May - 17 June. Only a few adults were recorded at each site. One exuvia was also collected at site 18. Carle (1982) recorded this species from only six counties in Virginia, but indicated that it was more common. We are aware of two other county records based on recent DNH surveys. Former DNH zoologist Kurt A. Buhlmann collected a male *A. villosipes* on 22 May 1991 in King George County. Another male was captured by CSH on 15 May 1994 in New Kent County. The latter record precedes the earliest Virginia flight date listed in Carle (1982) by eight days.

Gomphus exilis Selys

Sites 28, 31, and 34. 25 April - 28 April. This early species is probably more widespread on Fort A. P. Hill than our records indicate. One adult female was moderately infested with water mites. Carle (1982)

previously reported this species from Caroline County; a male was collected on 10 June 1978 at the U.S. Route 1 crossing of the North Anna River.

Gomphus lividus Selys

Sites 4, 14, 16, 47, and 48. 29 April - 9 May. This early species is probably more widespread on Fort A. P. Hill than our records indicate.

Hagenius brevistylus Selys

Sites 42 and 52. Three or four adult males were observed by SMR on 7 July 1994 while patrolling a 100 m section of Mill Creek at site 42; one voucher was collected. A male was also netted and released by CSH at site 52 on 12 August 1994.

Progomphus obscurus (Rambur)

Sites 30, 38, 42, and 51 (larvae). 7 July - 28 July. Only a few adults were recorded at the first three sites; two larvae were collected at the latter site.

Stylurus sp.

A male gomphid that was believed to be *S. laurae* (Williamson) was observed by SMR through binoculars on 17 July 1995 while perched on a leaf of the lowermost branch of an oak tree at site 41. The specimen evaded a subsequent capture attempt. Carle (1982) reported *S. laurae* from six counties in Virginia; the nearest records to Fort A. P. Hill are from Henrico and Louisa counties. The DNH reference collection contains a male of this species collected by Christopher A. Pague and Richard L. Hoffman on 15 September 1991 in Lunenburg County, which constitutes a new county record.

CORDULEGASTRIDAE

Cordulegaster bilineata (Carle)

This species was common on 25 April 1994 along the road and in several seepage ravines at site 34. At least 10 males were observed by SMR on this date, although none were seen in this same area one week earlier. This species

is probably more widespread on Fort A. P. Hill.

Cordulegaster erronea Hagen

This species was documented only by larval collections made at sites 33, 45, and 49. Carle (1982) recorded this species from eight counties in Virginia, primarily in the Blue Ridge region. No additional Virginia county records appear in his (Carle, 1989) comprehensive range map for this species. Carle (1979) listed *C. erronea* as "possibly endangered" in Virginia because only two extant populations were known in the state. In addition to our records from Caroline County, we have collected larvae in York County, which extends the state range of this species considerably further south into the Coastal Plain region. Recent collections obtained in southwestern Virginia primarily by Frank L. Carle (pers. comm.), as well as by DNH zoologists, reveal that this species is rather common, but locally distributed, in that portion of the state.

Cordulegaster maculata Selys

Two specimens were collected and several other adults were observed by SMR on 28-29 April 1995 along a small, sand-bottomed stream (Catlett Creek) at site 16. This species is probably more widespread on Fort A. P. Hill.

Cordulegaster obliqua (Say)

This species was documented only by the collection of two larvae at site 46. Carle (1982) reported this species from eight counties and cities in Virginia, and listed the flight period as 21 May to 10 July. In his earlier paper (Carle, 1979) on the rare dragonflies of Virginia, he indicated that eight extant populations of *C. obliqua* were known in the state and classified it as a "locally distributed species." We are aware of four other recent records for this species in Virginia (Fairfax, Greensville, Washington, and Wise counties) based on surveys by DNH biologists. All but the former are new county records.

CORDULIIDAE (MACROMIINAE)

Didymops transversa (Say)

Sites 28, 31, 34, 36, 47 (and a nearby pond not

marked on map), and 48. 18 April - 9 May. Only a few adults were recorded at each site. This early species is probably more common and widespread than our records indicate.

Macromia illinoensis georgina (Selys)

Adult males were collected at the following locations: along Campbell Road approximately midway between sites 19 and 20 (n = 1), site 40 (n = 2), and site 54 (teneral male collected on 17 June). Sight records of *Macromia* adults that are presumably assignable to this species were made at sites 20 and 41-44. Collectively, our specimen and observational records span the period from 17 June to 17 July. Suitable breeding habitat for this species on Fort A. P. Hill appears to be limited to free-flowing sections of Mill Creek. Some of the individuals seen on the base may have been strays from the nearby Mattaponi or Rappahannock rivers.

Donnelly & Tennessen (1994) recently synonymized *Macromia georgina* and *M. illinoensis*. Their study included seven specimens from four counties in northeastern Virginia (Piedmont region), as well as additional material from six counties in western Virginia. All of the samples from northeastern Virginia were scored as intergrades. These authors did not examine material from the Coastal Plain region of Virginia and assumed that only *georgina* occurs there (based on their range map). Carle (1982) reported both forms (as species) from Charlotte, Craig, Louisa and Nelson counties in Virginia, including one syntopic site (Twittys Creek) in the former county. Orr (1996) stated that the population at his study site in eastern Maryland was comprised of intergrades. Specimens from sites in eastern Virginia, including those collected at Fort A. P. Hill, should be evaluated further to determine their taxonomic status.

CORDULIIDAE (CORDULIINAE)

Epitheca cynosura (Say)

Sites 4, 18, 20, 28-29, 31, 34, 36, 39, 42, 47, and 59. 18 April - 31 May. This early species is undoubtedly much more common and widespread than our records indicate. One adult male was heavily infested with water mites.

Epitheca spinosa (Hagen)

Sites 29 and 59. 18 April - 25 April. Three males and two females were collected by SMR at site 29 on 18 April 1994; no adults were observed at this site one week later. A single male *E. spinosa* was collected by SMR among numerous *E. cynosura* males on 25 April 1994 over the road bordering site 59. Tennessen (1994) recently described the larva of *E. spinosa* and reported that the larval habitat is swamps, as opposed to boggy lakes for *E. canis*, which is known in Virginia only from one site in Highland County (Carle, 1982). Both of the sites where *E. spinosa* was found in Caroline County are exemplary, boggy ponds. No swamp habitat is present near either site, suggesting that these ponds provide suitable breeding habitat for *E. spinosa*.

This early spring species was recommended for state threatened status (not formally designated as such to date) by Carle (1991) because it was known only from two sites in southeastern Virginia (City of Suffolk and Southampton County). Carle (1979) had earlier classified it as a "locally distributed species." Three collection sites are listed by Carle (1982), who stated that *E. spinosa* is probably more common in the state, being undercollected because of its early flight season. The historical Virginia locality (1951 record; specimen deposited in the Illinois Natural History Survey collection) is also in Southampton County, at the old U.S. Route 58 crossing of a cypress swamp, approximately 16 mi (26 km) E of Emporia (R. L. Hoffnan, pers. comm.). The senior author recently discovered three previously unidentified males of *E. spinosa* in the USNM collection. All were collected on 12 April 1989 by W. E. Steiner along the Blackwater River 6 km S of Zuni (Isle of Wight County).

The only Virginia record plotted in Tennessen's (1994) recent range map for *E. spinosa* is from the City of Suffolk. Apparently, he was not aware of earlier maps (Carle, 1982, 1989, 1991) showing either one or two other records in the state. With a total of six documented sites, Virginia currently ranks third behind North Carolina (13 county records plotted in Tennessen, 1994) and New Jersey (four recent and five historical sites *vide* Barber, 1995 and May, 1995) in terms of the number of known localities per state for this infrequently collected species.

Helocordulia selysii (Hagen)

Two adult males were collected by SMR on 29 April 1995 at site 16. Other species found along this small, sand-bottomed stream were *Basiaeschna janata*, *Cordulegaster maculata*, and *Gomphus lividus*. Carle (1982) recorded this species from seven counties in eastern Virginia. He (1979) classified *H. selysii* as a "locally distributed species" and reported that only four extant populations were known in the state. Former DNH zoologist C. A. Pague collected a male of this species in Powhatan County on 24 April 1990, which constitutes a new county record.

Somatochlora filosa (Hagen)

One male was collected by CSH on 1 September 1994 along Polecat Creek at site 54. Gloyd (1951), Matta (1978), and Carle (1982) reported this species only from the cities of Chesapeake and Suffolk, and Southampton County, all in extreme southeastern Virginia. The Polecat Creek site is the northernmost documented locality for *S. filosa* in the state. Recent collections by DNH zoologist D. J. Stevenson are from the City of Virginia Beach and along the Blackwater River on the Isle of Wight-Southampton county line. The species ranges north to New Jersey.

Somatochlora linearis (Hagen)

This species is reported solely on the basis of sight records. Two or three adult males were observed by SMR on 13 September 1993 while patrolling at site 13. One of these males was studied with binoculars while briefly perched.

Somatochlora provocans Calvert

Sites 40 and 41. 7 July - 17 July*. All of the records obtained by SMR were of adults feeding over dirt roads; two males and two females were collected and several others were observed. No breeding sites were documented. Tennessen (1975) identified the larval habitat of this species as sphagnum seepage streams, which are a rather common habitat on Fort A. P. Hill. Carle (1979) classified *S. provocans* as "rare" in Virginia and reported that only one site was known in the state. Carle

(1982) indicated that the only Virginia record for this species was based on a male that he collected on 22 June 1975 in the Great Dismal Swamp National Wildlife Refuge, City of Suffolk. He remarked that this is one of the most difficult dragonflies to collect because it typically flies at heights of 5-15 m. Accordingly, Paulson & Dunkle (1995) have proposed the common name of "Treetop Emerald" for this species.

Somatochlora tenebrosa (Say)

Site 40; possibly also 11, 29, and 57. 7 July (- 27 September?). Two females were collected by SMR on 7 July 1994 while feeding along a dirt road (site 40) in the company of *S. provocans* and *Macromia illinoiensis georgina*. Sight records of *Somatochlora* adults that may refer to this species were made at sites 11, 29, and 57 (ovipositing female seen by CSH on 11 August 1994).

LIBELLULIDAE

Celithemis elisa (Hagen)

Sites 11 and 18. 1 June - 13 September*. Only a few individuals were noted at each site, including a male collected at site 11 on the latter date. Carle (1982) reported that the known Virginia flight period for this species extended through 24 August.

Celithemis eponina (Drury)

Sites 4, 18, and 29. 8 July - 27 September*. Only a few individuals were noted at each site. Our latest record (three adults seen at site 29) extends the Virginia flight period for this species six days beyond the date reported by Carle (1982).

Celithemis fasciata Kirby

Sites 3-5, 18, 23-24, 30-31, and 42. 16 June - 13 September*. Maximum count of 50+ adults at site 30 on 8 July 1994; fewer than five adults were observed at six of the eight sites. An adult male *C. fasciata* was photographed at site 18 while being eaten by a female *Erythemis simplicicollis*. Carle (1982) reported this species from 11 counties and cities in Virginia, his latest record being 6 August.

Celithemis martha Williamson

Sites 4-5, 18, 27-30, and 60. 8 July* - 27 September*. Maximum counts of 50+ adults at site 30 on 8 July 1994 and 30+ adults at site 27 on 27 September 1993. One male was collected from a spider web. Carle (1979) classified *C. martha* as a "locally distributed species" in Virginia, with only one known site in the state. This site was a pond in Fairfax County in northern Virginia, where he collected two males on 19 September 1978 (Carle, 1982). This record exceeded the latest flight date (7 September) listed for this species by Needham & Westfall (1955). Although our records significantly extend the known Virginia flight period, Barber (1994) has recently documented *C. martha* in New Jersey as late as 29 September. We observed 40-50 adults at three sites on 27 September 1993, suggesting that this species probably flies into October on Fort A. P. Hill.

Carle (1982) stated that the Fairfax County record was the southernmost known locality for *C. martha*. Concurrently, Huggins & Brigham (1982) included it in their list of species known from the Carolinas. However, White et al. (1980) did not mention *C. martha* in their compilation of South Carolina records, and there are no documented records of this species from North Carolina (R. D. Cuyler, pers. comm.). Therefore, because the record in Huggins & Brigham (1982) is not substantiated (D. G. Huggins, pers. comm.) and apparently erroneous, we conclude that a male collected on 12 August 1993 by SMR at the Route 656 Peatross pond (site 60) represents the southernmost documented locality for *C. martha*. This record extends the range of this species approximately 125 km S from the Fairfax County site. Other than the records discussed above, we are aware of only one other site for *C. martha* in Virginia. On 27 July 1995, SMR discovered a small, isolated population of this species in the Shenandoah Valley region of Augusta County at a site that harbors numerous Coastal Plain disjuncts among its flora and fauna. This is apparently the most inland population known of this northeastern Coastal Plain species. The site is approximately 150 km W of the Peatross pond. Both of these sites are located slightly below 38° N latitude.

Celithemis verna Pritchard

Sites 11, 28, 30, and 31. 1 June - 28 July. Maximum

count of 80+ adults at site 30 on 8 July 1994; at least 20 adults were also observed at this site (and site 31) on 28 July of the preceding year. The population at site 30 is the largest known in Virginia. One adult female was heavily infested with water mites.

Carle (1979) included this primarily austral species in his list of the state's rare dragonflies on the basis of only one known population. Carle (1982) reported two sites (both were recent) for *C. verna* in Virginia, both in the Piedmont region (Charlotte and Cumberland Counties). Our records from Fort A. P. Hill are the first for this species from the Coastal Plain region of the state. We have also collected *C. verna* in Augusta and Lee counties in western Virginia, bringing to five the total number of counties with confirmed records.

Carle (1982) indicated that this species is undercollected due to its early flight season, which he listed as 23 May - 18 June for Virginia. Our late date exceeds that (26 July) listed for *C. verna* by Needham & Westfall (1955). However, Tennessen et al. (1995) and Orr (1996) recently reported that this species has been found as late as 1 August in Alabama and 18 August in Maryland, respectively. Specimens of *C. verna* have also been collected by SMR as late as 18 August at the Augusta County, Virginia site.

Erythemis simplicicollis (Say)

Recorded at 22 sites on Fort A. P. Hill; also sites 58-60. 1 June - 27 September. This species is very common and widespread on the base.

Erythrodiplax minuscula (Rambur)

Sites 4, 8, 11, and 29. 12 August - 27 September*. Maximum count of 5-10 adults at site 4; only one adult male was found at sites 8 and 11. Our latest record (three males collected at site 29) extends the Virginia flight period for this species two days beyond the date reported by Carle (1982). He listed six county and city records for *E. minuscula* in Virginia, including adjacent Essex County. Our records from Fort A. P. Hill are the northernmost documented sites for this species in the state.

Donnelly (1961) reported that *E. minuscula* was last documented in the Washington, D.C. area in 1916. Orr (1995a, b, 1996) did not record this species at his study sites in eastern Maryland. Recent surveys by DNH

zoologists have shown that *E. minuscula* is fairly common in southeastern Virginia. One of us (SMR) has also collected this species at two sites in the western part of the state (Augusta and Grayson counties).

Libellula auripennis Burmeister

Sites 4, 7, 11, 18, 30, 31, and 58. 1 June - 18 August*. Maximum counts of 10+ adults at sites 30 and 31. Carle (1982) reported this species from six counties and cities in eastern Virginia and stated that it is not common in the state. Our records extend the Virginia flight period for *L. auripennis* eight days beyond his latest date. Recent surveys by DNH biologists have documented this species at approximately six sites in Augusta, Sussex, and York counties, and the City of Virginia Beach.

Libellula axilena Westwood

Sites 3-4, 6-7, 18, 29-30, and 59. 8 July - 17 August. Only one or two adults were observed at five of the eight sites; maximum count of 5-10 adults at site 6. Carle (1979) included this primarily austral species in his list of the state's rare dragonflies because only three extant populations were known to him at that time. Carle (1982) listed records from 10 counties and cities in Virginia. Observations by DNH zoologists during the past four years indicate that this species is fairly widespread in the state, and is occasionally abundant.

Libellula cyanea Fabricius

Sites 7, 10-11, 18, 29-31, 41-42, and 59. 31 May - 16 August. This species is common and fairly widespread on Fort A. P. Hill.

Libellula deplanata Rambur

Sites 1, 3-4, 11, 14, 18, 20, 28-29, 31, 36, 39, 48, and 59. 18 April - 1 June. This early species is undoubtedly more widespread on the base than our records indicate. It was abundant at several ponds. Several dead adults were found entangled in spider webs.

Libellula flavida Rambur

Sites 10-11, 18, 29-31, 35, and 59-60. 1 June - 27 September*. Maximum count of 10+ adults at site 35. A female was observed by SMR on 12 August 1993 while ovipositing in a shallow ditch bordering site 59. A male hovered near the female for several minutes until she apparently completed oviposition. This contrasts with Carle's (1982) statement that males of this species differ from other species of *Libellula* in this regard, and only watch their ovipositing mates from a perch or dart toward intruders.

Carle (1979) classified *L. flavida* as a "locally distributed species" in Virginia, with only two known extant populations in the state. Carle (1982) reported this species from 10 counties and cities in Virginia, his latest date being 7 August. We are aware of three other recent records for *L. flavida* in Virginia (Craig, Greensville, and Prince George counties) based on surveys by DNH biologists. All are new county records.

Libellula incesta Hagen

Recorded at 26 sites on Fort A. P. Hill; also five of the 10 off-base sites. 24 June - 4 October. This is one of the most common dragonflies on the base, and in the county.

Libellula luctuosa Burmeister

Sites 4, 17-18, 27-28, 30-31, 40, and 48. 9 May* - 27 September. Our early record precedes the earliest Virginia flight date listed in Carle (1982) by one day. This species is common and fairly widespread on Fort A. P. Hill.

Libellula lydia Drury

Sites 2, 10-11, 18, 28-29, 31, 38, 44, and 48; also six of the 10 off-base sites. 25 April - 27 September. This species is common and widespread on Fort A. P. Hill, and elsewhere in Caroline County.

Libellula pulchella Drury

This species was observed by CSH along Polecat Creek at site 52 on 12 August 1994, but no collections were made.

Libellula semifasciata Burmeister

Sites 4, 11, 16, 20, 26, and 29-30. 29 April - 8 July. This species is most common in the spring.

Libellula vibrans Fabricius

Sites 3-4, 6, 9-10, 41, 44, 52, and 55. 17 July - 18 August. Single individuals were seen at most sites. This species is probably more common than our records indicate.

Nannothemis bella (Uhler)

Sites 18 and 30. 31 May* - 28 July*. Roble & Stevenson (1994) reported that the discovery of this species at Fort A. P. Hill constituted the first records of *N. bella* in Virginia since 1890. New data obtained by SMR at these two sites since that paper appeared are: site 18 - observed 4 males on 31 May 1994 and 7 adults (5 males, 2 females) on 24 June 1994; site 30 - observed 50+ adults on 8 July 1994. Carle (1979) classified *N. bella* as a "locally distributed species" in Virginia, with no known extant populations in the state at that time.

Pachydiplax longipennis (Burmeister)

Recorded at 28 sites on Fort A. P. Hill; also six of the 10 off-base sites. 29 April - 4 October*. This is one of the most common dragonflies on the base. Our latest records (several adults observed on 4 October) extend the Virginia flight period for this species six days beyond the date reported by Carle (1982). On 11 August 1994, CSH observed a fishing spider (*Dolomedes* sp.) capture an ovipositing female *P. longipennis* at site 55. On a subsequent visit, he observed another fishing spider carrying a dead *P. longipennis*.

Pantala flavescens (Fabricius)

Sites 21 and 32. 8 July - 4 October. This species is reported solely on the basis of sight records. It was common in the parking lot and adjacent lawn area of the range control office (site 21) at Fort A. P. Hill.

Perithemis tenera (Say)

Sites 3-4, 17-18, 28, and 30-31. 24 June - 27 September. This small species is probably more common on Fort A. P. Hill than our records indicate.

Sympetrum ambiguum (Rambur)

SMR found 20-25 adults at site 11 on 13 September 1993, the only time that this southern species was detected on the base. Carle (1982) recorded *S. ambiguum* from only nine counties and cities in Virginia. Recent surveys by DNH zoologists indicate that this species is rather widespread in the Coastal Plain region of the state (nine new county records). We also have records from backwater pools along the Nottoway River straddling the Brunswick-Dinwiddie county line in the southern Piedmont.

Sympetrum vicinum (Hagen)

Recorded at 17 sites on Fort A. P. Hill; also site 60. 24 June - 22 November. This species is common and widespread on the base. Our late date (two males observed and a third collected by SMR) equals that reported for Virginia by Carle (1982).

Tamea carolina (Linnaeus)

Sites 4, 7-8, 11, 18, 20, 23, 27-28, and 30-31. 28 April - 27 September. This species is common and widespread on Fort A. P. Hill.

Tamea lacerata Hagen

This species is reported on the basis of a single sight record. An adult was observed briefly by SMR at site 4 on 13 September 1993.

DISCUSSION

Most of our surveys at Fort A. P. Hill were conducted in late summer and early fall. Rather limited sampling in late spring and early summer resulted in our failure to detect common, early-flying species at more sites than are reported herein. We may have entirely missed a few early species because of inadequate sampling during this period. Although our surveys spanned portions of four years, the overall effort directed toward Odonata was

roughly equivalent to a moderately intensive single year survey.

As illustrated in Figure 1, the northeastern portion of the base was not adequately surveyed. Also, because many of our faunal surveys of Fort A. P. Hill were not specifically directed at Odonata, it is very probable that some species were not detected. We estimate that another 10-15 species of Odonata could have been documented on the base with a more intensive survey. Furthermore, we believe that Fort A. P. Hill, primarily because of the presence of numerous oligotrophic, naturally acidic ponds (an uncommon habitat in Virginia), supports one of the most diverse and unique lentic Odonata faunas in Virginia. Additional acidic ponds that occur on privately owned lands in Caroline County may harbor similarly diverse lentic faunas.

Orr (1996) recorded an impressive total of 105 species of Odonata during a six-year study at and near the Patuxent Wildlife Research Center in eastern Maryland. This site straddles the Piedmont-Coastal Plain physiographic border and contains more significant lotic habitats (e.g., Patuxent River) than are present at Fort A. P. Hill. Consequently, he found a number of species that would not be expected at our study site. Cross (1955) recorded 58 dragonfly species (reported as 48) on the Savannah River Plant (= Savannah River Site) in South Carolina during a three-year survey. This site includes the Savannah River as well as five major stream systems; consequently, a significant percent of the total species that he documented were lotic forms. The Odonata fauna of Fort A. P. Hill contains a larger proportion of lentic species by comparison.

Table 3 summarizes the species recorded at the six ponds on Fort A. P. Hill with the greatest diversity of Odonata. Although we did not attempt to document breeding by every species listed in a particular column, we believe it is likely that most, if not all, of the lentic species bred at those ponds where they were recorded. Furthermore, as noted in the table, we visited each of these ponds only 2-6 times, and undoubtedly missed other species that inhabited these areas. The subtotals at the bottom of the table separate pond-breeding from stream- and seepage-breeding species. This analysis reveals that four of the ponds support a minimum of 25 species. Three of these ponds (sites 18, 29, and 30) were ranked by DNH ecologists as being among the most exemplary natural communities on Fort A. P. Hill on the basis of

their floristic diversity and composition (Fleming & Van Alstine, 1994).

Two of these same ponds (Bettys Bottom and Lonesome Gulch East) supported the largest percentage of uncommon and state-rare species of Odonata (Table 3), which ranks them among the most significant Odonata breeding habitats known in Virginia. Both ponds are fed by numerous seepages, which may provide larval habitat for *Tachopteryx thoreyi* (adults were found at both ponds). Although the greatest number of species was documented at the latter pond, we believe the former site is actually more significant for at least three reasons. First, because both of our visits to Bettys Bottom Pond were made in July (versus six visits in different seasons to Lonesome Gulch East) and were limited to two hours each, it is very probable that numerous (possibly 10 or more) early- and late-flying species were entirely missed during these surveys. Also, this pond supports breeding populations of five state-rare species of Odonata (versus three at Lonesome Gulch East), which clearly ranks it as an important site. Finally, Bettys Bottom Pond supports the largest known populations in Virginia of the following uncommon and state-rare species: *Celithemis martha*, *C. verna*, *Enallagma daeckii*, *Lestes vigilax*, *Nannothemis bella*, and *Nehalennia integricollis*. The *Anax longipes* population at this pond may also rank among the largest in the state. Further sampling of one of the Peatross ponds (site 59) may reveal that it is also one of the most significant breeding sites for Odonata in Virginia.

Carle (1979, 1991) published information on dragonfly species that he believed to be rare or endangered in Virginia. Of the 54 currently recognized species included in his 1979 list that are actually confirmed from Virginia, we documented 13 (24%) in Caroline County. However, we only found one of the 15 species (i.e., *Epitheca spinosa*) treated in his 1991 paper. Only 4-5 other species discussed in that paper are remotely possible in this county.

The 82 species documented in Caroline County represents 45 percent of the total Odonata fauna of Virginia (approximately 182 breeding species). An even greater proportion of the state's lentic fauna is represented by our samples. Few studies are available from other sites, counties or areas of Virginia that allow for comparison. Donnelly (1961) recorded a total of 114 species (112 are currently recognized) from the Washington, D. C. area, which included adjacent counties in Maryland and

Virginia. Many of these species inhabit the Potomac River. Matta (1978) recorded a total of 61 species (*Tramea onusta* was a misidentification *vide* Carle, 1982) from three counties and six cities in southeastern Virginia. After excluding four of Matta's (1978) species because they are primarily associated with coastal marshes, we found all but four of the 56 remaining species that he reported. All of these species, namely *Amphiagrion saucium* (Burmeister), *Gomphaeschna antilope* (Hagen), *Epithea princeps* Hagen, and *Pantala hymenaea* (Say), are likely to inhabit Caroline County and may occur on Fort A. P. Hill.

Roback & Westfall's (1967) study of lotic Odonata included records from the North Anna River in eastern Virginia. Their sampling stations ranged from the State Route 208 bridge (which now spans the Lake Anna Reservoir) to the river's mouth (confluence with the South Anna River). Although these authors identified this area as falling only within Louisa and Spotsylvania counties (they are on opposite sides of the river), the lower half of this reach actually forms the Caroline-Hanover county line. Of the 14 species reported with certainty by Roback & Westfall (1967) from the North Anna River, eleven are reported herein from Caroline County and another (*Stylurus laurae*) was possibly seen at Fort A. P. Hill. The two remaining species, *Argia sedula* Hagen and *Dromogomphus spinosus* Selys, probably occur in Caroline County and may inhabit Fort A. P. Hill.

Voshell & Simmons (1978) subsequently studied the Odonata fauna of the North Anna River for two years prior to and three years following impoundment. During the pre-impoundment portion of the study, they found four of the same species collected by Roback & Westfall (1967). Two other species (*Leucorrhinia frigida* Hagen and *Nehalennia* sp.) reported by Voshell & Simmons (1978) from the river are not usually associated with lotic habitats. The former is known elsewhere in Virginia only from one male collected by Frank L. Carle on 18 June 1978 in a boreal wetland in Highland County (Carle, 1982). This site is a more typical habitat for *L. frigida*. The three species of *Nehalennia* that occur in Virginia (Roble, 1994b) are typically found in lentic habitats, particularly boggy ponds (Walker, 1953; Dunkle, 1990; Carpenter, 1991; Orr, 1996). Voshell & Simmons (1978) also reported an unidentified species of *Neurocordulia* from the North Anna River. Based on the records in Carle (1982), this was most likely *N. obsoleta*

(Say). Members of this genus are crepuscular and easily missed if larval collections are not made. It is probable that *N. obsoleta* occurs in Caroline County, and it may inhabit Mill Creek on Fort A. P. Hill. *Enallagma basidens* Calvert, a species that colonized the impoundment (= Lake Anna) within two years of its formation, was not documented by us in Caroline County, but it undoubtedly occurs there.

Several of the species found by Orr (1996) at the Patuxent Wildlife Research Center in eastern Maryland may occur in Caroline County (possibly on Fort A. P. Hill) despite our failure to document them. Species included in this group that have not been discussed previously are *Stenogomphurus rogersi* (Gloyd), *Nehalennia gracilis* Morse, and *Stylurus plagiatus* (Selys). The nearest records of *S. rogersi* to our study area are from neighboring Essex and Spotsylvania counties (Carle, 1982; Donnelly, 1994). This species inhabits small, spring-fed muddy streams. Carle (1982) reported *S. plagiatus* from eight counties and cities in Virginia, the nearest record being in adjacent King William County. Orr (1996) also found *Aeshna mutata* Hagen at one pond on his study site, which is the only known Maryland locality. This lentic species is rare throughout its range in the eastern United States (Beatty & Beatty, 1969; Carle, 1989). It is known in Virginia only from Alleghany, Augusta, Craig, and Highland counties in the western part of the state (Carle, 1982, 1991; Hoffman, 1987). It is remotely possible that *A. mutata* inhabits Bettys Bottom Pond (site 30) on Fort A. P. Hill, but we were unable to gain access to this site during the late spring and early summer flight season of this species. In addition to Orr's (1996) records, several recent reports of *A. mutata* from Cape Cod, Massachusetts (Carpenter, 1991; Nikula & Sones, 1994) indicate that this species is not restricted to inland locations.

Orr (1995b) recorded 49 species of Odonata (reported as 48) along Nanjemoy and Beaverdam creeks in eastern Maryland (Charles County), including both species of *Helocordulia*. We found only *H. selysii* on Fort A. P. Hill, but *H. uhleri* (Selys) is also possible elsewhere in the county. Carle (1982) reported the latter species from 17 counties in Virginia, the nearest sites being in Hanover and Louisa counties. Other lotic species that may occur in Caroline County (possibly along Mill Creek on Fort A. P. Hill) include *Gomphus apomyius* Donnelly, *Hetaerina titia* (Drury), and *Somatochlora georgiana* Walker. These

species are rare to uncommon in Virginia (Carle, 1991; Roble, 1994b); they were not found by Orr (1995b).

Stevenson et al. (1995) reported the uncommon damselfly *Ischnura prognata* (Hagen) from widely scattered sites in eastern Virginia, primarily in the southeastern corner of the state. However, one of their records was from a seepage swamp in Fairfax County in northeastern Virginia. This species may occur on Fort A. P. Hill, particularly in the swampy habitats near site 44, which we did not survey thoroughly. Localized populations of the damselfly *Telebasis byersi* and the green treefrog, *Hyla cinerea* (Schneider), were found in this area (Roble, 1994a; Roble & Stevenson, 1996; also see species account for *T. byersi* above).

Comprehensive data on the number of Odonata species documented from each county and county-sized city in Virginia are currently lacking. However, we analyzed the records in Carle (1982) to determine the number of dragonfly species known from each county or city in the state as of that date. Our total of 53 species for Caroline County exceeds the totals for all other counties, only slightly surpassing Highland (52), Fairfax (51), and Montgomery (50) counties. Each of these three counties has been collected rather extensively. No other county or city had more than 40 species listed in Carle (1982).

Comparative data are available for a number of areas in the northeastern United States. Beatty & Beatty (1971) stated that the Odonata fauna of Pennsylvania was perhaps the best known of any state at the time of their report (many additional records have also been obtained during the past quarter century [C. N. Shiffer, pers. comm.]). However, only four counties had more than 80 species recorded, with one exceeding 100 species. The latter (Centre County with 107 species as of 1971) contains Ten Acre Pond, a well-known Odonata collecting site where 74 species have been documented during numerous surveys spanning the past four decades (Shiffer & White, 1995). Donnelly (1992) reported that approximately 100 species of Odonata were known from three counties in New York; no other county total exceeded 80 species. The southernmost two counties in New Jersey have been surveyed intensively for Odonata in recent years. Barber (1994) found 103 species in Cumberland County, and 90 species are known from neighboring Cape May County (Soltesz, 1991; additional species provided by K. Soltesz, pers. comm.). A total of 97 species was recorded on Cape Cod (Barnstable County),

Massachusetts during extensive surveys by Gibbs & Gibbs (1954) and Carpenter (1991). The recent study of Orr (1996), which documented 105 species at several nearby sites between Baltimore and Washington, D.C. in eastern Maryland, was discussed previously.

Table 4 summarizes the degree of similarity between the Odonata fauna of Caroline County and those reported for other selected areas in the eastern United States. Orr's (1996) study area in eastern Maryland has the most similar fauna (highest percent similarity). His surveys yielded all but four of the species known from Caroline County (i.e., *Calopteryx dimidiata*, *Enallagma dubium*, *Erythrodiplax minuscula*, and *Telebasis byersi*). Of the Virginia sites included in this table, the fauna of Highland County is the least similar to that of Caroline County (based on Anisoptera only). This is not surprising given the fact that the former includes many boreal (northern) and montane species, whereas the latter has a preponderance of austral (southern) and Coastal Plain species.

The composition of the Odonata fauna of Caroline County is varied, and includes some species with boreal and austral affinities, as well as numerous wide-ranging eastern North American species, several transcontinental species, and one nearly cosmopolitan species (*Pantala flavescens*). The overall trend is decidedly biased toward austral rather than boreal species. Species (n = 34, or 41.5% of the county fauna) that are broadly distributed in the eastern United States (the ranges of some extend into southern Canada) include: *Argia apicalis*, *A. fumipennis*, *A. tibialis*, *Basiaeschna janata*, *Boyeria vinosa*, *Calopteryx maculata*, *Celithemis elisa*, *C. eponina*, *Cordulegaster maculata*, *C. obliqua*, *Didymops transversa*, *Enallagma divagans*, *E. exsulans*, *E. geminatum*, *E. signatum*, *E. vesperum*, *Epithecina cynosura*, *Gomphaeschna furcillata*, *Gomphus lividus*, *Hagenius brevistylus*, *Ischnura posita*, *Lestes inaequalis*, *L. rectangularis*, *L. vigilax*, *Libellula cyanea*, *L. luctuosa*, *L. semifasciata*, *Macromia illinoensis*, *Nasiaeschna pentacantha*, *Perithemis tenera*, *Somatochlora linearis*, *S. tenebrosa*, *Sympetrum vicinum*, and *Tamea carolina*. Species (n = 9, or 11.0%) that have essentially transcontinental distributions (includes "American" species of Beatty & Beatty, 1971) include *Anax junius*, *Argia moesta*, *Enallagma civile*, *Erythemis simplicicollis*, *Ischnura hastata*, *Pachydiplax longipennis*, *Libellula lydia*, *L. pulchella* and *Tamea lacerata*.

The remaining species have predominantly northern

or predominantly southern distributions. The following species ($n = 8$, or 9.8%) fall into the former group: *Aeshna umbrosa*, *Argomphus villosipes*, *Celithemis martha* (northeastern), *Chromagrion conditum*, *Enallagma aspersum*, *Gomphus exilis*, *Lestes congener*, and *Nannothemis bella*. Beatty & Beatty (1971) classified *A. umbrosa* and *L. congener* as Transcontinental-Northern species. Many more of the species documented in Caroline County have predominantly austral distributions. These species ($n = 29$, or 35.4%) are *Anax longipes*, *Argia bipunctulata*, *Calopteryx dimidiata*, *Celithemis fasciata*, *C. verna*, *Cordulegaster bilineata*, *C. erronea*, *Enallagma daeckii*, *E. dubium*, *E. traviatum*, *Epiaeschna heros*, *Epitheca spinosa*, *Erythrodiplax minuscula*, *Helocordulia seelyi*, *Ischnura kellicotti*, *I. ramburii*, *Libellula auripennis*, *L. axilena*, *L. deplanata*, *L. flavida*, *L. incesta*, *L. vibrans*, *Nehalennia integricollis*, *Progomphus obscurus*, *Somatochlora filosa*, *S. provocans*, *Sympetrum ambiguum*, *Tachopteryx thoreyi*, and *Telebasis byersi*. *Lestes disjunctus australis* also has a predominantly southern distribution, the nominate subspecies being the more northern form. Our surveys have established new range limits for two of the above species, including one northern species (*Celithemis martha*) and one southern species (*Telebasis byersi*).

Interest in the need to preserve global biodiversity has increased significantly in the past decade, with particular concern expressed for tropical habitats (Wilson, 1992). One of the key challenges associated with conducting biological surveys in the tropics is the need to estimate total species richness from short-term, intensive sampling. Coddington et al. (1991) and Colwell & Coddington (1994) discuss a variety of methods that can be employed to estimate total species richness from available data. One of these techniques involves the preparation of "species accumulation curves," in which the cumulative number of species recorded from a site or area is plotted as a function of the sampling effort. Such curves are generally steep during the early phases of sampling when many species are documented quickly, but then gradually level off as fewer additional species are found with more sampling effort. Theoretically, a point is reached when no amount of additional sampling results in the documentation of more species, because the entire species assemblage has, in fact, already been documented. Louton et al. (1996) prepared a species accumulation curve for the Odonata fauna of a site (primarily tropical lowland forest) in Peru,

using the number of specimens collected per day as their measure of collecting effort. This is the only species accumulation curve for Odonata that we have seen in the literature. Their graph shows a steady increase in the documented number of new members of the local fauna through about day 40, then begins to level off gradually during the remaining 26 sampling days.

We subjected our records from Fort A. P. Hill to a similar analysis in an attempt to determine if our earlier prediction of 10-15 additional species was reasonable. This estimate was based on our knowledge of the distribution and habitat requirements of potential but undocumented species (some were discussed above), and the fact that undescribed taxa were highly unlikely to be present on the base (an unsafe assumption in tropical habitats). The data used to prepare our graph (Figure 2) differ from those of Louton et al. (1996) in the following important respects: (1) because our data are a composite of specimen and sight records, and the total number of individuals observed or collected was not recorded for every species (particularly common ones), we used the number of species (not individuals) recorded per survey site on a given day as our measure of sampling effort; (2) the x-axis of our graph represents the number of discrete surveys (we often visited several sites per day) that we conducted, as opposed to the number of collecting days in Louton et al. (1996); and (3) data from the few surveys conducted prior to July 1993 were pooled on a daily basis, because few specimens were collected and information on sight records was fragmentary or lacking. We only included records of adult Odonata in our analysis, thereby eliminating two species of *Cordulegaster* that were documented by larval collections. We lumped all surveys conducted on 1 November 1993 because adult Odonata were not seen on the base that day (survey number 33). We readily acknowledge that a number of factors, including search time (we did not use time-constrained searches), time of day, weather, and partial rather than complete access to a few sites (due to safety concerns), are partly responsible for variable survey results.

The graph in Figure 2 follows the predicted curve illustrated in Colwell & Coddington (1994) through survey 34, which was the last survey of 1993. This portion of the graph clearly shows that we had thoroughly sampled the late summer and fall Odonata fauna of Fort A.P. Hill. Surveys by SMR during 1994 (numbers 35-58; latest survey on 8 July) and 1995 (numbers 59-70; latest

survey on 17 July) primarily added spring and early summer species of Odonata that were missed in 1993 due to inadequate sampling prior to July of that year. Considering only damselflies, 19 of the 25 species (76%) that were documented on Fort A. P. Hill were found during the first 20 surveys. Only four additional species were recorded during the next 20 surveys, and the last two species were found during the final 30 surveys (including *Telebasis byersi* on the last survey). The graph reveals that half of the documented Odonata fauna of the base was found during the first seven surveys (=10% of total surveys). The trajectory of the curve appears to support our earlier prediction that 10-15 additional species of Odonata are likely to inhabit Fort A. P. Hill, and that a figure approaching Orr's (1996) total of 105 species is remote.

As noted in the opening paragraph of this paper, the Odonata faunas of many counties in Virginia are poorly known. A review of the records in Carle (1982) reveals that only one of the most common dragonflies in the state (i.e., *Libellula bydia*) has been recorded from at least half of the counties and large cities of Virginia. The fortuitous opportunities that allowed us to sample the fauna of selected portions of Caroline County at a moderately intensive level, have revealed that the Odonata fauna of this area of the state is very rich in lentic species, and includes numerous state-rare, uncommon, or locally distributed species. New range limits were also established for two species in the process. We encourage other naturalists to investigate the local fauna of their area because much remains to be learned about the distribution and biology of Odonata in the Commonwealth.

ACKNOWLEDGMENTS

A preliminary version of this paper based on data collected through 1993 was presented at the first meeting of the Virginia Natural History Society held in conjunction with the Virginia Academy of Science.

Our surveys at Fort A. P. Hill and Polecat Creek were funded by contracts between the U.S. Department of Defense (Department of the Army) and the Virginia Department of Conservation and Recreation, Division of Natural Heritage (DCR-DNH), and the Chesapeake Bay Local Assistance Department (CBLAD) and DCR-DNH, respectively. Funding for the Fort A. P. Hill surveys was spawned by a cooperative agreement signed in December

of 1988 between the U.S. Department of Defense (DOD) and The Nature Conservancy, which was designed to maintain biological diversity on DOD installations nationwide. Funding for the Polecat Creek contract was provided by the Virginia Coastal Resources Management Program at the Department of Environmental Quality through Grant #NA57OZ0561 of the National Oceanic and Atmospheric Administration (NOAA), Office of Ocean and Coastal Resource Management, under the Coastal Zone Management Act of 1972, as amended. The views expressed in this paper are solely those of the authors and do not necessarily reflect the views of NOAA or any of its subagencies, the Department of Defense (Department of the Army), or the U.S. government.

We thank the various training area schedulers, range control officers and escorts, and natural resource personnel at Fort A. P. Hill for facilitating our surveys on the base and ensuring our safety in the process. We thank Jean N. Tingler of CBLAD for logistical support associated with the Polecat Creek surveys, and the various private landowners in the watershed who granted access to their properties.

DCR-DNH botanists and ecologists who directed us to significant wetlands on Fort A. P. Hill were Gary P. Fleming, J. Christopher Ludwig, and Nancy E. Van Alstine. The field efforts of DCR-DNH zoologists Philip H. Stevenson and Dirk J. Stevenson are greatly appreciated. Dirk generously permitted us to include several of his unpublished records of Odonata from other sites in Virginia in this paper. He also provided helpful comments on an earlier version of the manuscript. Other current or former DCR-DNH biologists who contributed one or more records are Kurt A. Buhlmann, Kennedy H. Clark, J. Christopher Ludwig, and Christopher A. Pague. Kurt also identified several of the *Cordulegaster* nymphs, one of which he deposited in the University of Georgia Entomological Collection. Kenneth J. Tennessen verified our identification of *Epithea spinosa*.

The senior author would like to thank Dr. Oliver S. Flint, Jr. and Ms. Nancy E. Adams of the National Museum of Natural History for the many courtesies they extended to him during visits to examine the Odonata collection in their care. He also expresses thanks to Robert D. Barber, Jerry A. Louton, and Richard L. Orr for providing copies of unpublished manuscripts or reports. Finally, the senior author would like to thank his family for graciously allowing him to devote numerous

evening and weekend hours toward the tasks of compiling records, analyzing data, and preparing the manuscript.

LITERATURE CITED

- Barber, R. D. 1994. Damselflies and dragonflies of Cumberland County, New Jersey. Cape May Bird Observatory, New Jersey Audubon Society, Cape May Point, New Jersey. 38 pp. plus Errata/Addenda.
- Barber, R. D. 1995. A historical perspective and preliminary notes on the rediscovery of *Tetragoneuria (Epitheca) spinosa* (robust baskettail) in New Jersey. Unpublished manuscript. 3 pp.
- Beatty, A. F., & G. H. Beatty. 1971. The distribution of Pennsylvania Odonata. *Proceedings of the Pennsylvania Academy of Science* 45: 147-167.
- Beatty, G. H., & A. F. Beatty. 1969. Evolution and speciation in the subgenus *Schizuraeschna*, with observations on *Aeshna (Schizuraeschna) mutata* Hagen (Odonata). *Proceedings of the Pennsylvania Academy of Science* 43: 147-152.
- Carle, F. L. 1979. Environmental monitoring potential of the Odonata, with a list of rare and endangered Anisoptera of Virginia, United States. *Odonatologica* 8: 319-323.
- Carle, F. L. 1982. A contribution to the knowledge of the Odonata. Unpublished Ph.D. thesis, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 1095 pp.
- Carle, F. L. 1989. The endangered dragonfly fauna of New Jersey. Pp. 119-148, 239 In E. F. Karlin (ed.), *New Jersey's Rare and Endangered Plants and Animals*. Institute for Environmental Studies, Ramapo College of New Jersey, Mahwah, New Jersey.
- Carle, F. L. 1991. Dragonflies. Pp. 197-214 In K. Terwilliger (coord.), *Virginia's Endangered Species*. McDonald and Woodward Publishing Company, Blacksburg, Virginia.
- Carpenter, V. 1991. Dragonflies and Damselflies of Cape Cod. Cape Cod Museum of Natural History, Natural History Series No. 4. 79 pp.
- Coddington, J. A., C. E. Griswold, D. S. Dávila, E. Peñaranda, & S. F. Larcher. 1991. Designing and testing sampling protocols to estimate biodiversity in tropical ecosystems. Pp. 44-60 In Dudley, E. C. (ed.), *The Unity of Evolutionary Biology: Proceedings of the Fourth International Congress of Systematic and Evolutionary Biology*, Dioscorides Press, Portland, Oregon.
- Colwell, R. K., & J. A. Coddington. 1994. Estimating terrestrial biodiversity through extrapolation. *Philosophical Transactions of the Royal Society of London, B* 345: 101-118.
- Cross, W. H. 1955. Anisopteran Odonata of the Savannah River Plant, South Carolina. *Journal of the Elisha Mitchell Scientific Society* 71: 9-17.
- Donnelly, T. W. 1961. The Odonata of Washington, D.C., and vicinity. *Proceedings of the Entomological Society of Washington* 63: 1-13.
- Donnelly, T. W. 1973. The status of *Enallagma traviatum* and *westfalli* (Odonata: Coenagrionidae). *Proceedings of the Entomological Society of Washington* 75: 297-302.
- Donnelly, T. W. 1992. The Odonata of New York. *Bulletin of American Odonatology* 1: 1-27.
- Donnelly, T. W. 1994. Some recent records of interest. *Argia* 6(1-2): 13.
- Donnelly, T. W., & K. J. Tennessen. 1994. *Macromia illinoensis* and *georgina*: a study of their variation and apparent subspecific relationship (Odonata: Corduliidae). *Bulletin of American Odonatology* 2: 27-61.
- Dunkle, S. W. 1981. The ecology and behavior of *Tachopteryx thoreyi* (Hagen) (Anisoptera: Petaluridae). *Odonatologica* 10: 189-199.
- Dunkle, S. W. 1989. Dragonflies of the Florida Peninsula, Bermuda and the Bahamas. Scientific Publishers, Gainesville, Florida. 155 pp.
- Dunkle, S. W. 1990. Damselflies of Florida, Bermuda

- and the Bahamas. Scientific Publishers, Gainesville, Florida. 148 pp.
- Fleming, G. P., & N. E. Van Alstine. 1994. A natural heritage inventory of Fort A. P. Hill, Virginia. Natural Heritage Technical Report 94-1, Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond. 196 pp. plus appendices.
- Funderburg, J. B. 1974. A preliminary ecological survey of the Mattaponi-Polecat Creek swamp in Caroline County, Virginia. Bulletin of the Maryland Herpetological Society 10: 73-76.
- Garrison, R. W. 1991. A synonymic list of the New World Odonata. Argia 3(2): 1-30.
- Gibbs, R. H., Jr. & S. P. Gibbs. 1954. The Odonata of Cape Cod, Massachusetts. Journal of the New York Entomological Society 62: 167-184.
- Gloyd, L. K. 1951. Records of some Virginia Odonata. Entomological News 62: 109-114.
- Hoffman, R. L. 1987. Local sites of special concern in Virginia. Virginia Journal of Science 38: 399-408.
- Huggins, D. G., & W. U. Brigham. 1982. Odonata. Pp. 4.14.100 In A. R. Brigham, W. U. Brigham, & A. Gnilka (eds.), Aquatic Insects and Oligochaetes of North and South Carolina. Midwest Aquatic Enterprises, Mahomet, Illinois.
- Johnson, C., & M. J. Westfall, Jr. 1970. Diagnostic keys and notes on the damselflies (Zygoptera) of Florida. Bulletin of the Florida State Museum, Biological Series 15: 45-89.
- Louton, J. A., R. W. Garrison, & O. S. Flint. 1996 (in press). The Odonata of Parque Nacional Manu, Madre de Dios, Peru; natural history, species richness and comparisons with other Peruvian sites. Pp. 421-439 In Wilson, D. E., & A. Sandoval (eds.), La Biodiversidad del Sureste del Peru: Manu (Biodiversity of Southeastern Peru). Editorial Horizonte, Lima, Peru.
- Matta, J. F. 1978. An annotated list of the Odonata of southeastern Virginia. Virginia Journal of Science 29: 180-182.
- May, M. L. 1995. The subgenus *Tetragoneuria* (Anisoptera: Corduliidae: *Epitheca*) in New Jersey. Bulletin of American Odonatology 2: 63-74.
- Needham, J. G., & H. B. Heywood. 1929. A Handbook of the Dragonflies of North America. Charles C. Thomas, Springfield, Illinois and Baltimore, Maryland. 378 pp.
- Needham, J. G., & M. J. Westfall, Jr. 1955. A Manual of the Dragonflies of North America (Anisoptera), including the Greater Antilles and the Provinces of the Mexican Border. University of California Press, Berkeley. 615 pp.
- Nikula, B., & J. Sones. 1994. Highlights: Spring/early summer 1994. Ode News 1(2): 1-3.
- Orr, R. L. 1995a. Odonata of Plummers Island. Argia 7(1): 6-10.
- Orr, R. L. 1995b. Great blue herons, dwarf wedge mussels, and gray petaltails. Argia 7(3): 19-21.
- Orr, R. L. 1996. The dragonflies and damselflies of Patuxent Wildlife Research Center and vicinity. Unpublished report to Patuxent Wildlife Research Center. 54 pp. (Abridged version to be published in the Bulletin of American Odonatology)
- Pague, C. A. 1991. Carpenter frog, *Rana virgatipes* Cope. Pp. 426-427 In K. Terwilliger (coord.), Virginia's Endangered Species. McDonald and Woodward Publishing Company, Blacksburg, Virginia.
- Paulson, D. R., & S. W. Dunkle. 1995. Proposed English names for the Odonata of North America. Unpublished manuscript. 4 pp.
- Roback, S. S., & M. J. Westfall, Jr. 1967. New records of Odonata nymphs from the United States and Canada with water quality data. Transactions of the American Entomological Society 93: 101-124.
- Roble, S. M. 1994a. Field notes: *Hyla cinerea* (Green

treefrog). *Catesbeiana* 14: 40.

Roble, S. M. 1994b. A preliminary checklist of the damselflies of Virginia, with notes on distribution and seasonality (Odonata: Zygoptera). *Banisteria* 4: 3-23.

Roble, S. M. 1995. Geographic distribution: *Siren intermedia intermedia* (Eastern lesser siren). *Herpetological Review* 26: 150-151.

Roble, S. M. 1996. Natural Heritage Resources of Virginia: Rare Animal Species. Natural Heritage Technical Report 96-11. Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond. 23 pp. plus appendices.

Roble, S. M., & C. S. Hobson. 1994. Field notes: *Farancia erythrogramma* (Rainbow snake). *Catesbeiana* 14: 15-16.

Roble, S. M., & D. J. Stevenson. 1996. First records of *Telebasis byersi* from Virginia, including a new northern range limit. *Argia* 8(1): 13-14.

Roble, S. M., & P. H. Stevenson. 1994. Rediscovery of the dragonfly *Nannothemis bella* Uhler in Virginia (Odonata: Libellulidae). *Banisteria* 3: 27-28.

Shiffer, C. N., & H. B. White. 1995. Four decades of stability and change in the Odonata populations at Ten Acre Pond in central Pennsylvania. *Bulletin of American Odonatology* 3: 31-41.

Soltész, K. 1991. A survey of the damselflies and dragonflies of Cape May County, New Jersey. Cape May Bird Observatory, New Jersey Audubon Society, Cape May Point, New Jersey. 54 pp.

Stevenson, D. J., S. M. Roble, & C. S. Hobson. 1995.

New records of the damselfly *Ischnura prognata* in Virginia. *Banisteria* 6: 26-27.

Tennessee, K. J. 1975. Description of the nymph of *Somatochlora provocans* Calvert (Odonata: Corduliidae). *The Florida Entomologist* 58: 105-110.

Tennessee, K. J. 1994. Description of the nymph of *Epitheca (Tetragoneuria) spinosa* (Hagen) (Odonata: Corduliidae). *Bulletin of American Odonatology* 2: 15-19.

Tennessee, K. J., J. D. Harper, & R. S. Krotzer. 1995. The distribution of Odonata in Alabama. *Bulletin of American Odonatology* 3: 49-74.

Voshell, J. R., Jr., & G. M. Simmons, Jr. 1978. The Odonata of a new reservoir in the southeastern United States. *Odonatologica* 7: 67-76.

Walker, E. M. 1953. The Odonata of Canada and Alaska. Volume One. University of Toronto Press, Toronto. 292 pp.

Walker, E. M. 1958. The Odonata of Canada and Alaska. Volume Two. University of Toronto Press, Toronto. 318 pp.

Walker, E. M., & P. S. Corbet. 1975. The Odonata of Canada and Alaska. Volume Three. University of Toronto Press, Toronto. 308 pp.

White, T. R., K. J. Tennessee, R. C. Fox, & P. H. Carlson. 1980. The aquatic insects of South Carolina. Part I: Anisoptera (Odonata). *South Carolina Agricultural Experiment Station Bulletin* 632: 1-153.

Wilson, E. O. 1992. *The Diversity of Life*. The Belknap Press of Harvard University Press, Cambridge, Massachusetts. 424 pp.

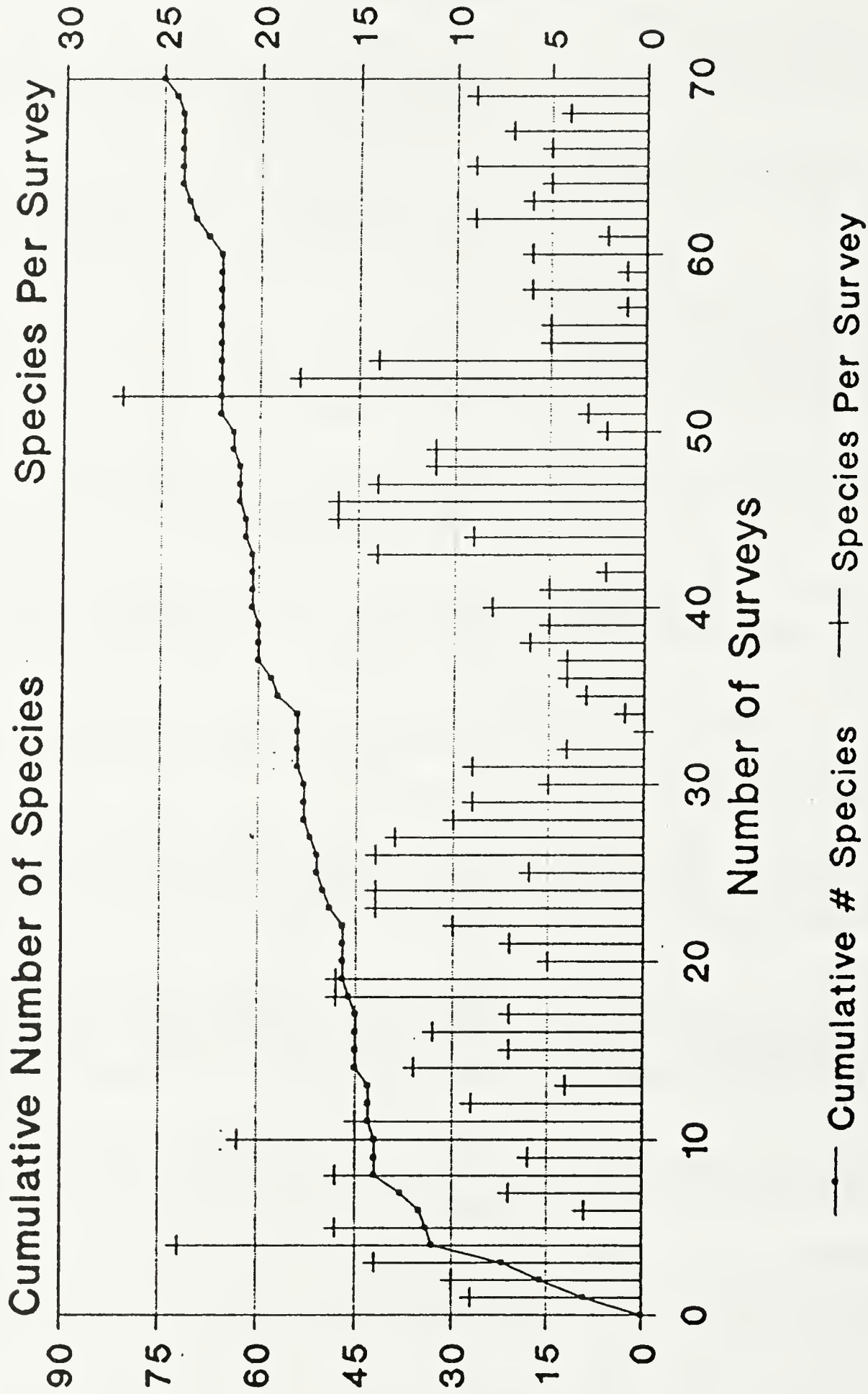


Figure 2. Species accumulation curve for Odonata at Fort A. P. Hill, Caroline County, Virginia.

Table 2. Seasonal distribution of Odonata at Fort A. P. Hill and vicinity, Caroline County, Virginia.

Month	April	May	June	July	August	Sept.	Oct.	Nov.	Early and Late Flight Dates
Species	Quarter ^a	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	* = Extreme date for Virginia ^b
<i>Calopteryx dimidiata</i> <i>C. maculata</i>			x xx		x x x xx	xx			18 May - 28 July 18 May - 16 August
<i>Lestes congener</i> <i>L. disjunctus australis</i> <i>L. inaequalis</i> <i>L. rectangularis</i> <i>L. vigilax</i>		x		x			x		4 October 25 April - 4 October 16 June - 1 September 11 August - 10 September 24 June - 4 October
<i>Argia apicalis</i> <i>A. bipunctulata</i> <i>A. fumipennis violacea</i> <i>A. tibialis</i> <i>Chromagrion conditum</i>				x					17 June 8 July - 4 October* 31 May - 4 October* 18 May* - 28 July 25 April* - 29 April
<i>Enallagma aspersum</i> <i>E. civile</i> <i>E. daeckii</i> <i>E. divagans</i> <i>E. dubium</i> <i>E. geminatum</i> <i>E. signatum</i> <i>E. traviatum</i> <i>E. vesperum</i>									17 August 27 September 31 May* - 28 July 17 June 24 June* - 27 September* 18 August - 13 September 31 May - 27 September* 24 June 31 May - 12 August*
<i>Ischnura hastata</i> <i>I. kellicotti</i> <i>I. posita</i> <i>I. ramburii</i> <i>Nehalennia integricollis</i> <i>Telebasis byersi</i>		x		x	x x	xx	x x	x	25 April - 4 October 31 May* - 12 August 18 April - 4 October 25 April* - 27 September 1 June* - 13 September 17 July*

ROBLE & HOBSON: ODONATA OF FORT A. P. HILL.

Table 2 (continued).

Species	Month Quarter ^a	April	May	June	July	August	Sept.	Oct.	Nov.	Early and Late Flight Dates
		1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	* = Extreme date for Virginia ^b
<i>Tachopteryx thoreyi</i>			x		x					27 May - 28 July
<i>Aeshna umbrosa</i>					x					17 July
<i>Anax junius</i>		x	x	x	x	x	x			25 April - 27 September
<i>A. longipes</i>					x					8 July - 28 July*
<i>Basiaeschna janata</i>		x								28 April - 29 April
<i>Boyeria vinosa</i>					x		x	x		7 July - 4 October
<i>Epiaeschna heros</i>		x								29 April - 12 August
<i>Gomphaeschna furcillata</i>		x				x				29 April
<i>Nasiaeschna pentacantha</i>		x	x							31 May*
<i>Arigomphus villosipes</i>				x						31 May - 17 June
<i>Gomphus exilis</i>		x								25 April - 28 April
<i>G. lividus</i>		x	x							29 April - 9 May
<i>Hagenius brevistylus</i>					x					7 July - 12 August
<i>Progomphus obscurus</i>					x					7 July - 28 July
<i>Stylurus</i> sp. (<i>laurae</i> ?)					x					17 July
<i>Cordulegaster bilineata</i>		x								25 April
<i>C. maculata</i>		x								28 April - 29 April
<i>Didymops transversa</i>			x							18 April - 9 May
<i>Macromia illinoensis georgina</i>				x	x					17 June - 17 July
<i>Epithea cynosura</i>		x								18 April - 31 May
<i>E. spinosa</i>		x								18 April - 25 April
<i>Helocordulia sefysii</i>		x								29 April
<i>Somatochlora filosa</i>							x			1 September
<i>S. linearis</i>										13 September
<i>S. provocans</i>					x					7 July - 17 July*
<i>S. tenebrosa</i>					x					7 July (- 27 September?)

Table 2 (continued).

Month	April	May	June	July	August	Sept.	Oct.	Nov.	Early and Late Flight Dates
Species	Quarter ^a	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	* = Extreme date for Virginia ^b
<i>Celithemis elisa</i>				x x					1 June - 13 September*
<i>C. eponina</i>					x	x			8 July - 27 September*
<i>C. fasciata</i>				x	x x	xx			16 June - 13 September*
<i>C. martha</i>					x x	xx			8 July* - 27 September*
<i>C. verna</i>				x	x x				1 June - 28 July
<i>Erythemis simplicicollis</i>				x x	x xx	xxx			1 June - 27 September
<i>Erythrodiplax minuscula</i>						xx			12 August - 27 September*
<i>Libellula auripennis</i>				x xx	x x	xx			1 June - 18 August*
<i>L. axilena</i>					x xx	xxx			8 July - 17 August
<i>L. cyanea</i>				x	x xx	xxx			31 May - 16 August
<i>L. deplanata</i>		xx	xxx	x					18 April - 1 June
<i>L. flavida</i>				x x	x x	xxx			1 June - 27 September*
<i>L. incesta</i>					xx	xxx		x	24 June - 4 October
<i>L. luctuosa</i>				x	x x	xxx			9 May* - 27 September
<i>L. lydia</i>		x	x x	x xx	x xx	xxx			25 April - 27 September
<i>L. pulchella</i>						x			12 August
<i>L. semifasciata</i>		x	x	x xx	x				29 April - 8 July
<i>L. vibrans</i>					x	xx			17 July - 18 August
<i>Nannothemis bella</i>					x x				31 May* - 28 July*
<i>Pachydiplax longipennis</i>		x	x	x xx	x xx	xxx		x	29 April - 4 October*
<i>Pantala flavescens</i>					x x			x	8 July - 4 October
<i>Perithemis tenera</i>					x	x x			24 June - 27 September
<i>Sympetrum ambiguum</i>									13 September
<i>S. vicinum</i>					x	x xx		x	24 June - 22 November*
<i>Tramea carolina</i>		x		x xx	x x	x			28 April - 27 September
<i>T. lacerata</i>									13 September

^aQuarters of the month: 1st to 8th (1), 9th to 15th (2), 16th to 23rd (3), and 24th to the end of the month (4); no data for underlined quarters.

^bExceeds or equals early or late date reported by Carle (1982) or Roble (1994b); see species accounts for more details.

TABLE 3. Species recorded at the six ponds on Fort A. P. Hill which contained the highest documented species diversity of Odonata. Collection or sight records at a given pond do not necessarily confirm breeding at that site.

SPECIES RECORDED	POND NAME AND MAP LOCATION					
	Bettys Bottom (30)	Hickory Fork (31)	Jordan Crossing (4)	Lodge (11)	Lonesome Gulch East (18)	Smoots North (29)
ZYGOPTERA						
<i>Calopteryx maculata</i>	x	-	-	-	-	x
<i>Lestes disjunctus australis</i>	-	-	-	x	-	-
<i>Lestes inaequalis</i>	-	-	x	-	x	-
<i>Lestes vigilax</i>	x	-	x	-	x	x
<i>Argia fumipennis violacea</i>	x	-	x	x	x	x
<i>Argia tibialis</i>	x	-	-	-	-	-
<i>Chromagrion conditum</i>	-	x	-	-	-	-
<i>Enallagma daeckii</i>	x	x	-	x	x	x
<i>Enallagma dubium</i>	-	-	x	-	x	-
<i>Enallagma geminatum</i>	-	-	x	-	-	-
<i>Enallagma signatum</i>	x	-	x	-	x	-
<i>Enallagma traviatum</i>	-	-	-	-	x	-
<i>Enallagma vesperum</i>	-	-	-	-	x	-
<i>Ischnura hastata</i>	x	x	x	x	x	x
<i>Ischnura kellicotti</i>	-	-	-	-	x	-
<i>Ischnura posita</i>	x	x	x	x	x	x
<i>Ischnura ramburii</i>	-	-	-	-	x	x
<i>Nehalennia integricollis</i>	x	-	x	x	-	-
ANISOPTERA						
<i>Tachopteryx thoreyi</i>	x	-	-	-	x	-
<i>Anax junius</i>	x	x	x	x	x	x
<i>Anax longipes</i>	x	-	-	-	-	-
<i>Basiaeschna janata</i>	-	-	x	-	-	-
<i>Gomphaeschna furcillata</i>	-	-	x	-	-	-
<i>Arigomphus villosipes</i>	-	-	-	-	x	-
<i>Gomphus exilis</i>	-	x	x	-	-	-
<i>Gomphus lividus</i>	-	-	x	-	-	-
<i>Progomphus obscurus</i>	x	-	-	-	-	-
<i>Didymops transversa</i>	-	x	-	-	-	-
<i>Epithea cynosura</i>	-	x	x	-	x	x
<i>Epithea spinosa</i>	-	-	-	-	-	x
<i>Somatochlora</i> sp. (<i>tenebrosa?</i>)	-	-	-	x	-	x
<i>Celithemis elisa</i>	-	-	-	x	x	-
<i>Celithemis eponina</i>	-	-	x	-	x	x
<i>Celithemis fasciata</i>	x	x	x	-	x	x
<i>Celithemis martha</i>	x	-	x	-	x	x
<i>Celithemis verna</i>	x	x	-	x	-	-
<i>Erythemis simplicicollis</i>	x	x	x	x	x	x
<i>Erythrodiplax minuscula</i>	-	-	x	x	-	x

TABLE 3 (continued).

POND NAME AND MAP LOCATION

SPECIES RECORDED	Bettys Bottom (30)	Hickory Fork (31)	Jordan Crossing (4)	Lodge (11)	Lonesome Gulch East (18)	Smoots North (29)
<i>Libellula auripennis</i>	x	x	x	x	x	x
<i>Libellula axilena</i>	x	-	x	-	x	x
<i>Libellula cyanea</i>	x	x	-	x	x	x
<i>Libellula deplanata</i>	-	x	x	x	x	x
<i>Libellula flavida</i>	x	x	-	x	x	x
<i>Libellula incesta</i>	x	x	x	x	x	x
<i>Libellula luctuosa</i>	x	x	x	-	x	-
<i>Libellula lydia</i>	-	x	-	x	x	x
<i>Libellula semifasciata</i>	x	-	x	x	-	x
<i>Nannothemis bella</i>	x	-	-	-	x	-
<i>Pachydiplax longipennis</i>	x	x	x	x	x	x
<i>Perithemis tenera</i>	x	x	x	-	x	-
<i>Sympetrum ambiguum</i>	-	-	-	x	-	-
<i>Sympetrum vicinum</i>	x	x	x	x	x	x
<i>Tramea carolina</i>	x	x	x	x	x	-
<i>Tramea lacerata</i>	-	-	x	-	-	-
Number of surveys ^a	2	2	4	3	6	4
Total species (54)	29	22	31	23	34	26
Pond species (47)	25	21	29	23	33	25
Stream or seepage species (7)	4	1	2	0	1	1
Common species (30)	18	16	21	16	20	18
Watchlist species (16)	6	5	7	5	11	6
State-rare species (7)	5	1	3	2	3	2
Percent watchlist + state-rare species	38	27	32	30	41	31

^aExcludes 1 November 1993 surveys when no adult Odonata were observed on the base.

Table 4. Comparison of the Odonata fauna of Caroline County, Virginia, with other areas in the eastern United States.

Reference	State	Locality/County	Total species	Species shared with Caroline Co. ^a	Overlap as percent of Caroline Co. fauna	Percent Similarity ^b
Cross 1955	SC	Savannah River Plant	58 ^c	40	75.5	0.56
Matta 1978	VA	Southeast corner	60	52	63.4	0.58
Carle 1982	VA	Fairfax County	51 ^c	36	67.9	0.53
	VA	Highland County	52 ^c	23	43.4	0.28
	VA	Montgomery County	50 ^c	35	66.0	0.51
Donnelly 1961	VA/MD	Washington, D.C. area	112	70	85.4	0.56
Orr 1996	MD	Patuxent Wildlife Research Center and vicinity	105	78	95.1	0.72
Orr 1995a	MD	Plummers Island, Potomac River	42	28	34.1	0.29
Orr 1995b	MD	Nanjemoy & Beaverdam creeks, Charles County	49	42	51.2	0.47
Shiffer & White 1995	PA	Ten Acre Pond, Centre County	74	41	50.0	0.36
Barber 1994	NJ	Cumberland County	103	71	86.6	0.62
Soltesz 1991(+ pers. comm. additions)	NJ	Cape May County	90	63	76.8	0.58
Gibbs & Gibbs 1954, Carpenter 1991	MA	Cape Cod (= Barnstable County)	97	55	67.0	0.44

^aBased on 82 total confirmed Odonata in Caroline County, including 53 Anisoptera^bPercent Similarity = Number of Shared Species / (Total Species from Caroline Co. + Total Species from Comparison Area - Number of Shared Species)^cAnisoptera only